PROCEDURE FOR INCREASING THE FILTRATE VOLUMETRIC FLOW RATE DURING SEPARATION PROCESSES, WHICH ARE ACCOMPANIED BY THE FORMATION OF A FILTER CAKE, AND A DEVICE FOR CARRYING OUT THE PROCEDURE

Specification

Area

The invention pertains to a procedure for increasing the filtrate volumetric flow rate during separation processes, which are accompanied by the formation of a filter cake, with use being made of at least one filter element.

In addition, the invention pertains to a device for carrying out the procedure in accordance with the invention.

Prior art

Periodic cleaning to remove the filter cake from the filter medium that takes place as required during cake-forming filtration when the filtrate volumetric flow rate falls below a defined magnitude, which is critical from economic standpoints, forms part of the current prior art. The starting conditions, which prevail after cleaning to remove a previously built up filter cake, can generally be reproduced in subsequent filtration cycles. However, account needs to be taken of the fact that progressive so-called "shifting" of the filter medium can lead to permanent worsening of the starting situation for the following filtration cycle after removing the filter cake. In such cases, additional cleaning of the filter medium, e.g. by means of back flushing, needs to be undertaken after a defined number of filtration cycles. Depending on the microstructure of the filter cake that is being built up, the cleaning intervals are independent, in a product specific manner, of the height of the filter cake that has formed, but they are dependent on the permeability of the filter cake and on the filtrate volumetric flow rate that is directly dependent thereon. The necessary periodic removal of the filter cake from a filtration apparatus can take place mechanically in different ways. Typical examples are "peeling off" in the case of so-called stripping centrifuges, spinning off in the case of hood-type filter centrifuges, or jettisoning the filter cake by means of movement/deformation of the filter medium (e.g. in the case of filter presses).

Filter cake build up takes place steadily in all conventional types of filtration apparatus under, generally speaking, a constantly applied pressure difference over the filter medium or filter cake. This filtration pressure difference that is employed is produced hydrostatically (via the difference in height between the suspension stock supply container and the filter unit), or via superimposed static [pressure] (produced by means of e.g. a pump or imposed gas pressure), or via centrifugal forces (in centrifuges and decanters).

Non-compressible filter cakes are generally assumed in the conventional design of filtration systems or filtration processes. The need to take account of the compressibility of the filter cake is the subject of very recent research studies but has gained entry only empirically into technical filtration practice thus far. A defined analytical description of filter cake compressibility, and its effects on the structure of the filter cake and the filtration process with the objective of transferal to an industrial process do not form part of the prior art thus far. Empirical optimization of the filtration pressure, and the maximum filter cake height, and the maximum duration of the filtration cycle that is linked thereto has taken place for highly compressible filter cake systems thus far.

Problem

The problem that forms the basis of the invention is to increase the filtration efficiency during separation processes in all conventional types of filtration apparatus, devices, machines, and installations, such as e.g. centrifuges, drum filters, filter presses, etc.

Another problem that forms the basis of the invention is to provide a suitable device for carrying out the procedure that has been striven for in accordance with the invention.

Solution to the problem regarding the procedure

This problem is solved by each of the patent claims 1 and 2.

Some advantages

The microstructure of compressible filter cake systems experiences loosening as a result of changes in pressure, whereby this loosening is not spontaneously reversible upon re-imposing the original filtration pressure, and it thus permits an increased filtrate

volumetric flow rate over a certain time span (the relaxation time of the filter cake structure). It is assumed that such an irreversible loosening of the filter cake structure takes place in an especially pronounced manner when the pressure is relieved in an abrupt manner, and the compressible components of the filter cake are re-deformed abruptly in approximately the same way. The elastic properties of the filter cake structure elements constitute a prerequisite for such re-deformation. Such elastic properties are present in a plurality of products, especially those from the area comprising biological raw materials, and also for a number of non-organic materials, e.g. plastic polymer products.

In the event of exceeding defined pressure change amplitudes and especially with filter cake systems that are assembled from particles with a more narrow particle size distribution, it has been found, surprisingly, that especially intense loosening of the filter cake, which is irreversible over a defined time scale, is achieved in the case when elastic properties of the filter cake elements are present. It is assumed that the filter cake microstructure is altered in such an intense way upon exceeding a critical re-deformation when the pressure is relieved that the arrangement of the filter cake structure elements needs a certain time (the so-called structure relaxation time of the filter cake) after re-applying the filtration pressure in order to restore the compacted "stationary" filter cake structure that was present prior to the pressure being relieved. In accordance with the invention, the filter cake structure relaxation time defines the minimum frequency of the pressure changes that are applied in order to increase the filtrate volumetric flow rate. In accordance with the invention, the frequency of the pressure changes realized in the process is higher than the previously described minimum pressure change frequency.

The implementation of the invention in accordance with the invention preferably takes place by imposing a stress that is caused by static pressure changes as a result of gas pressure or hydraulic pressure in pressure filters, and in vacuum filters, and hyperbaric filter centrifuges. The pressure changes can be achieved as a result of the imposition of gas pressure, or hydraulically with or without a superimposed centrifugal field (filter centrifuges).

Additional inventive processes

These are described in patent claims 3 through 20.

Solution to the problem regarding the device

This problem is solved by the features of patent claim 21.

Some advantages

The device in accordance with the invention can, to a large extent, be constructed with conventional commercial construction elements, and it provides a safe and reliable process when using the procedure in accordance with the invention.

Additional inventive forms of embodiment

Additional inventive forms of embodiment are described in patent claims 22 through 30.

Summarizing, the invention therefore provides an advantageous process and device in the case of which solid/liquid separation is undertaken - in the way in which this takes place in pressure filters and vacuum filters and likewise in filter centrifuges in the case of so-called cake-forming filtration - but in an improved manner as a result of the superimposition of pressure changes. The build up of a filter cake from the solid particles that are to be separated is a consequence of the nature of cake-forming filtration. The microstructural features of the filter cake determine the ability of the filtrate to pass through it (permeability). The filtrate volumetric flow rate becomes too small to carry out the process economically in the event of exceeding a defined filter cake height for a given filter cake microstructure and pressure difference over the height of the filter cake height that can be maximally achieved from the process technical standpoint. This is all the more pronouncedly the case if the solid particles, which form the filter cake, form a more compact, i.e. less porous, filter structure. Such a case is assisted by any pronounced breadth of the particle size distribution and by the increased compressibility of the solid particles as a result of their plastic and/or elastic deformability under the influence of pressure.

Such elastic/plastic deformation properties are present, in particular, in the case of solid particles that comprise a biological material, and frequently also in the case of plastics (e.g. elastomers). The consequence of this for the filter cake is compressibility.

If a compressible filter cake, which is being permeated by the filtrate under a

defined applied pressure gradient, undergoes pressure relief, i.e. the applied pressure difference is reduced, then re-deformation of the compressible filter and hence concomitant loosening thereof take place. Such loosening is accompanied by an increase in the permeability of the filter cake. If the original increased filtration pressure difference is re-imposed on such a filter cake that has undergone pressure relief, then - in the case where the original compressed structural state of the filter cake is not spontaneously re-established - an increase in the filtrate volumetric flow rate arises within the characteristic time span that is necessary in order to reduce the permeability of the filter cake once again as a result of its re-solidification or the additional build up of its layer thickness.

In accordance with the invention, the amplitude of the pressure changes between the state of imposition of filtration pressure and the state where pressure relief takes place is optimized with respect to the compressibility of the filter cake or the solid particles that form the filter cake. In accordance with the invention, optimization of the frequency of the pressure changes takes place as a function of the relaxation time of the filter cake structure. The latter is defined as the time that is necessary in order for the filter cake structure to become compacted to such an extent under given operational conditions that the original permeability prior to carrying out pressure relief is once again achieved.

In accordance with the invention, compressible auxiliary substances can be introduced, in particulate form, into the filter cake in order to amplify the temporary loosening effect that has been described during pressure relief. Such auxiliary substances can be e.g. highly compressible elastic caoutchouc granular materials. Elastically deformable layers in the filter medium (filter cloth) offer a further possibility, whereby these lead to pronounced deformation or re-deformation during pressure stress changes in such a way that structural loosening or structural rupture takes place in the filter cake structure that is located above them.

The invention is illustrated by way of example - partly schematically - in the drawings. The following aspects are shown.

Fig. 1 shows a circuit diagram of a device in accordance with the invention;

Fig. 2 shows a diagram of the filtrate volumetric flow rate V versus the time t as a function of the imposed pressures or pressure changes;

Fig. 3 shows an additional circuit diagram of a hyperbaric beaker centrifuge; and

Fig. 4 again shows the filtrate volumetric flow rate V versus the time t as illustrated in the case of hyperbaric centrifugation with pressure changes.

Figs. 1 and 2 illustrate the procedure in accordance with the invention when in use in a pressure filtration plant.

The suspension supply line is designated 1 and the compressed gas line is designated 2, while 3 represents a valve, e.g. a motor operated valve.

The suspension that is to be treated is conveyed from a pressure-sealed suspension stock supply container 4 to the filtration process zone 8 via a supply pipeline 5. Either a pump can serve as the conveying entity, or excess pressure can be built up in the suspension stock supply container 4 for conveyance purposes. In accordance with the invention, the build up of pressure in the suspension stock supply container 4 takes place by means of superimposed static gas pressure that is built up as a result of admitting compressed gas (e.g. air) via the compressed gas line 2 that is fed in from a pressure tank or from a compressed gas network (not illustrated). In the case of imposing pressure changes in accordance with the invention, a control/regulating unit, which is actuated via a microcomputer 14, carries out the defined adjustment of the pressure amplitude and the frequency of the pressure changes.

The following form part of the pressure regulation device: the valve 3 in the compressed gas line 2 to the suspension stock supply container 4; a pressure relief valve 13 that is connected to the gas zone of the suspension stock supply container 4; and a pressure recorder 10 that measures the static pressure in the suspension stock supply container 4, preferably in the gas zone. A large cross section for the compressed gas line 2 to the suspension stock supply container 4 and a small gas zone in the suspension stock supply container 4 ensure the possibility of a rapid build up and decline, respectively, in pressure. Pressure amplitudes that are typical of the process are 0.1 to 5 bar, but, in special procedures in which e.g. one is working with small volumes and very high pressures, these pressure amplitudes can be distinctly higher, i.e. up to several hundred bar. Typical pressure change frequencies are in the 0.01 to 1 Hz range but, in special cases, they can be expanded to higher

or lower frequencies. If the imposition of pressure takes place - as described - via the suspension stock supply tank 4, then in order to manage the forces that arise on the material of the tank it is preferable to select slim tank constructions with small lid surface areas and increased wall thicknesses.

In a special form of embodiment of the subject of the invention, the pressure is built up in the suspension supply line 1 to the filtration apparatus or directly in the filtration chamber on the side where the suspension is located in the way that has been described before for the suspension stock supply tank, whereby the connection of the filtration apparatus and the suspension stock supply tank is closed by a valve 15 during the time for building up the pressure. In this way, the suspension stock supply container 4 does not experience any increase in pressure, and it does not therefore have to be designed for high pressures. The compressed gas line 2 and the pressure relief line with the associated valves are connected directly to the supply pipeline 5 or to the filtration chamber 8.

For in-line control of the permeability of the filter cake, the pressure difference 7 over the height of the filter cake is measured by means of pressure recorders 11, 12 during e.g. an experimental run, and the filtrate volumetric flow rate is measured in the same way by means of mass-based flow meters 9, or gravimetrically at the filtrate outlet.

In a special form of embodiment of the subject of the invention, the imposition of pressure changes on the filter system can be controlled as a function of the pressure difference over the filter cake, or as a function of the filtrate mass-based flow rate. In this case, a single or multiple pressure change of defined height [sic; amplitude] and frequency is initiated with the help of the pressure regulation device in the event of falling short of the critical volumetric flow rate for the filtrate or, respectively, in the event of exceeding the critical pressure difference over the filter cake. The optimization of the measurement of the critical parameters and the initiation of the valve switching processes take place via the microprocessor computer 14 that can be part of e.g. a memory programmable control unit (SPS). In the case of inadequate efficiency of the pressure changes that have taken place in order to increase the filtrate volumetric flow rate, the process control/regulation unit can successively increase the pressure amplitude and the frequency of the pressure changes, on the basis of an optimization program, up to the corresponding limiting values that are fixed in the control/regulation program.

In accordance with the invention, the device's adaptation, which has been described, to the pressure filter system can be transferred in an identical manner to the hyperbaric filter centrifugation system that is illustrated in an exemplary manner in Figs. 3 and 4. The sole difference is the filtration zone that corresponds to the centrifuge drum 8, or the centrifuge beakers (in the case of beaker centrifuges). In the case of a hyperbaric centrifuge, the feeding in of the suspension takes place centrically via a hollow shaft or filling pipe 17. A sealing supply line up to pressures of approximately 10 bar, by means of a filling pipe, forms part of the prior art. The centrifuge housing and the drive motor are designated in Fig. 3 as additionally listed plant components for a hyperbaric beaker centrifuge. The control computer (microcomputer 14 in Fig. 2) is not shown explicitly in Fig. 3. Naturally, such a computer can also be connected to the hyperbaric filter centrifuge in the same way as in the case of the pressure filtration plant. The control or regulation of the imposed pressure change stressing in accordance with the invention takes place in an identical manner to that for the pressure filtration plant in accordance with Fig. 1.

A supporting framework or holder is designated 16, whereas the filter medium or filter element is designated 16.

Example 1

In the case of the pressure filtration apparatus that is illustrated in Fig. 1 and Fig. 2, a model filter cake comprising a caoutchouc granular material has been pre-coated and built up to a height of 40 mm. The caoutchouc granular material that is used is considered to be representative of the elastically deformable microstructure elements of typical compressible filter cake systems. It was possible to impose a static gas pressure or static gas pressure changes in a defined manner in the stock supply container of the pressure filtration apparatus. The filtrate volumetric flow rate through the filter cake was measured gravimetrically. The static pressures in front of and behind the filter cake were measured by means of absolute pressure recorders during the experimental run.

Fig. 2 shows a diagram of the filtrate volumetric flow rate V versus the time t as a function of the imposed pressures or pressure changes. For a pressure change amplitude of 1 bar [translator: there is no verb in this "sentence"]. As can be seen clearly from Fig. 2, an improvement, i.e. an increase, in the filtrate volumetric flow rate relative to the stationary experimental arrangement takes place in the filtration process that is cyclically subjected to

pressure.

Example 2

In order to achieve an increase in the filtrate volumetric flow rate or in order to achieve shorter process times in the case of hyperbaric filtering centrifugation, a static pressure field over the height of the filter cake is superimposed on the constantly acting centrifugal field. In the proposed experimental arrangement, an alternating pressure field - in contrast to a static pressure field - is imposed, in a superimposed manner, on the applied centrifugal field. By way of example, the experimental run took place in a hyperbaric beaker filtration centrifuge whose structural arrangement is illustrated in Fig. 3. The defined imposition of pressure with a constant static pressure or pressure that changes in a defined manner took place as in the case of the pressure filtration apparatus, namely via the static gas pressure in the suspension stock supply container 4. The filtrate volumetric flow rate V versus the time t is again illustrated in Fig. 4. The same effect is found in the case of hyperbaric centrifugation as was the case with the example of pure pressure filtration, namely that a distinct increase in the filtrate volumetric flow rate can be achieved with defined pressure change amplitudes. Unsuitable pressure amplitudes can give rise to a counterproductive effect. This supports the finding in accordance with the invention that defined optimal pressure differences, which depend on the structure of the filter cake, have to be set up for the pressure changes in order to permit sufficient loosening effects to arise along with an increase in the filtrate volumetric flow rate that results from the structure relaxation time of the filter cake.

On the basis of previous investigations, it is assumed that the minimum pressure change amplitude and the minimum pressure change frequency depend unambiguously on the structural parameters of the filter cake, whereby exceeding these [minima] contributes to an increase in the filtrate volumetric flow rate and hence distinctly improves the economics of the filtration procedure. For example, it has been possible to show that filter cakes with a narrower particle size distribution already exhibit the positive effect of an increase in filtrate volumetric flow rate with smaller pressure amplitudes. It is assumed on the basis of the complexity of real filter cake systems that the minimum pressure change amplitude and the minimum pressure change frequency, which are determined experimentally in laboratory experiments for the particular filter cake system, are then transferred to the industrial scale process.

In accordance with the invention, the following actions, which are more far reaching, can be undertaken in order to increase the cake loosening effect via pressure changes.

a) Elastic particles with good compressibility properties are added, in the form of an auxiliary filtering agent, to the suspension that is to be filtered.

b) The filter medium (e.g. filter cloth) is provided with compressible "inclusions" (e.g. hollow fibers or hollow spheres comprising an elastic material).

In both cases, the elastically deformable and compressible elements, which are deposited in the filter cake or in the filter cloth, bring about amplified re-deformation following pressure relief and hence concomitant loosening of the cake. The resultant pore widening is accompanied by increased permeability and hence an increase in filtrate volumetric flow rate.

The filter cake's structure relaxation time, which arises in accordance with the nature of the filter cake and the operating conditions, can be explained in terms of the aspect that the particles, which are arranged in the filter cake, need "structure specifically" differing lengths of time in order to re-achieve their "favorable" stable position in the filter cake structure.

The features, which are described in the abstract, and in the patent claims, and in the specification, and which can be seen from the drawings, can be essential, both individually and also in any desired combinations, for the realization of the invention.

List of reference symbols

1	suspension supply line
2	compressed gas line
3	valve
4	suspension stock supply container
5	supply pipeline
6	-
7	pressure difference
8	filtration process zone (centrifuge drum, centrifuge beaker) with filter medium, filtration chamber
9	mass-based flow meter
10	pressure recorder
11	" "
12	" "
13	pressure relief valve
14	microcomputer
15	valve
16	supporting framework, holder
17	filling pipe
18	filter medium/filter element
19	drive motor

SPS memory programmable control unit

t time

V filtrate volumetric flow rate